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The Derived Demand for Real Cash Balances in Agricultural Production

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INTRODUCTION

The effect of real money balances on consumption is well known as the Pigou effect. It asserts that increases in real money balances held by the private sector increase consumption. The role of money in production is, however, less well understood. In fact, Moroney's (1972) observation that the theory of money has not been satisfactorily integrated with the pure theory of production remains credible more than a decade later.

One economic rationale for including money in the production function is that money increases the efficiency of obtaining physical inputs necessary for production and marketing. In agriculture, real cash balances may also mitigate problems associated with the timing of input purchases. That is, money may facilitate the purchase of inputs in situations where the production process is lengthy and the receipt of revenues is delayed. If real cash balances play an important role in agricultural production, and it is the maintained hypothesis of this analysis that they do, then money balances have implications for specifying the "true" production function and empirically estimating the derived demand for inputs.

The objectives of this analysis are twofold. The first objective is to develop and evaluate the reasonableness of an agricultural production model which treats real cash balances as a productive input. The second objective is to evaluate the implications of such a specification for the derived demand for inputs. The approach used for this analysis utilizes results from duality theory on the correspondence between the production and cost function. A system of aggregate input demand functions for agriculture are derived and estimated assuming producers minimize input costs for a given output level. Results suggest real cash balances do play a role in agricultural production decisions.

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The theoretical approach adopted here treats real cash balances as a conventional neoclassical production input.1/ Friedman was among the first to suggest that money should be treated as another productive input rather than as a buffer or shock absorber as in inventory theoretic approaches. Early empirical applications include Johnson (1968) and Levhari and Patinkin (1968) who include real cash balances in an aggregate production function as part of a macroeconomic growth model. Sinai and Stokes (1972) tested this approach using a Cobb-Douglas production function. Nadiri (1969) and Dennis and Smith (1978) also utilized a neoclassical approach and examined a representative firm's demand for real cash balances.2/ Nadiri's work demonstrates that a firm's demand for real cash balances depends, in part, on the prices of other inputs. Furthermore, his work suggests that the level of money held by the firm affects the cost of adjusting inputs. The most obvious reason for including money in production models is that firms hold cash balances.3/ The forces compelling firms to hold money are the same forces which compelled the transition of barter to market economies: efficiencies in exchange. Levhari and Patinkin (1968) assert "money is held only because it enables the economic unit in question to acquire or produce a larger quantity of commodities in the usual sense of the word." They cite as money's principal contribution to productivity "that an economy without money would have to devote effort (read: labor and capital) in order to achieve the multitude of 'double coincidences' - of buyers who want exactly what the seller has to offer - on which successful barter is based."

A strict interpretation of a production function as an engineering concept tests the credulity of treating real cash balances as a production input.4/ Certainly money is not of the same character as diesel fuel or chemicals and does not directly enter a narrow definition of the production process. However, a broader definition of the production process, more conducive for economic analysis, includes not only engineering relationships which transform inputs to outputs, but also the production functions performed by money, such as facilitating the purchase of inputs. This characterization follows Fischer's (1974) suggestion that economists distinguish between a technical production function and a "delivered output" production function which encompasses the contributions of real cash balances and physical inputs as well. The delivered output production function is of particular economic interest because abstract engineering or technical renderings of the production process tends to be unrealistic because they depict the flow of production as being instantaneously created. In reality, the flow of production is not instantaneous. Instead, a buildup period occurs

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1/ Alternative approaches include models based on inventory theory (Baumol, 1952), portfolio choice (Tobin, 1965), and transactions costs (Gabor and Pearce, 1968). For a more extensive review see Moroney (1972).

2/ The literature distinguishes between macroeconomic and microeconomic applications of real cash balances (Dennis and Smith, 1978). It is argued that only microeconomic applications provide sufficient motivation for including real cash balances in production models. The insufficiency of behavioral motivations in macroeconomic models is not, however, unique to this question.

3/ Money or cash balances is liquid fiat serving as a generally accepted means of exchange.

4/ Consider, for example, Shephard's (1970) definition of a production function as "a mathematical summary of the output implied by the use of specific inputs within alternative feasible arrangements of the technical process involved in production."

where inputs are purchased and accumulated, production is created, output is marketed, and revenue is recovered. It is the time dimension of production flow which argues for including real cash balances in the delivered output production function.

THEORETICAL MODEL

The underlying theoretical framework utilizes results from duality theory on the correspondence between the firm's production and cost function (Diewert, 1974). If competitive behavior and a well-behaved technology are assumed, then there exists a one-to-one correspondence between a firm's production and cost function. It is possible, therefore, to completely describe a firm's technology from the cost function (McFadden, 1978).

The cost function, which assumes cost minimization subject to a given output level is approximated in this analysis with a translogarithmic function (Christensen, Jorgenson, and Lau, 1973).5/ This form does not restrict *a priori* the nature of substitution possibilities and allows direct testing for the role of real cash balances. The translog cost function is:

$$\ln C = a + a_y \ln Y + 1/2\ b_{yy} \ln Y^2 + \sum_{i=1}^{n} b_i \ln P_i$$
$$+ 1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \ln P_i \ln P_j + \sum_{i=1}^{n} b_{yi} \ln P_i \ln Y \qquad (1)$$

where C is total cost, Y is output, P_i's are factor prices, and a's and b's are parameters. If longrun equilibrium is assumed then, applying Shepard's Lemma to the translog cost function implies a cost-share system of the form:

$$\partial \ln C / \partial \ln P_t = S_i^* = b_i + \sum_{j=1}^{n} b_{ij} \ln P_j + b_{yi} \ln Y \qquad (2)$$

where S_i^* is the optimal input share for the ith input.

Symmetry and homogeneity of factor prices are imposed by:

$$b_{ij} = b_{ji}$$

$$\sum_{i=1}^{n} b_{ij} = \sum_{j=1}^{n} b_{ji} = \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} = 0, \sum_{i=j}^{n} b_i = 1. \qquad (3)$$

5/ In this analysis, the translog cost function is interpreted as a second-order approximation to any arbitrary cost function.

The equilibrium own-price and cross-price elasticities, holding output constant, are:

$$(\partial X_i^*/\partial P_i)\ (P_i/X_i^*) = [S_i^{*2} - S_i^* + b_{ij}]/S_i^* \qquad (4)$$

$$i = 1,2,\ldots, n$$

$$(\partial X_i^*/\partial P_j)\ (P_j/X_i^*) = [S_i^*\ S_j^* + b_{ij}]/S_i^* \qquad (5)$$

$$i = j = 1,2,\ldots, n$$

where X_i^* is the optimal quantity of the ith input.

The symmetry conditions imposed in equation (3) imply only that:

$$\partial X_i/\partial P_j = \partial X_j/\partial P_i \qquad i = j = 1,2,\ldots, n \qquad (6)$$

Factor price homogeneity implies that the equilibrium price elasticities sum to zero.

EMPIRICAL MODEL

The theoretical model is modified by treating land as a quasi-fixed factor to mitigate the confounding effect of acreage control programs prevalent throughout the 1960's and 1970's as well as identification problems frequently encountered when estimating input demand equations for land. If a constant returns to scale technology is assumed and homogeneity and symmetry restrictions are imposed, then the ith input share equation is:

$$S_i = a_i + \sum_{j=1}^{n-1} b_{ij} \ln(P_j/P_n) + c_i \ln Z + e_i \qquad i = 1,2,\ldots,n \qquad (7)$$

where Z is the stock of land, c_i is a parameter, and e_i an appended classical error term.6/ The input share system is composed of four variable inputs: labor, machinery (producers durable equipment), money, and intermediate inputs. This share equation is interpreted as being derived from a shortrun variable cost function and represents the locus of shortrun cost-minimizing solutions as a function of output, factor prices, and quantities of fixed factors.

6/ More general specifications which did not impose constant returns to scale were also estimated. A likelihood ratio test of the null hypothesis, no statistical difference between the general and restricted models, could not be rejected. Therefore, only the constant returns to scale model is presented here.

DATA

The analysis uses aggregate annual time series data for the years 1955 through 1978. Data consisted of observations on aggregate agricultural output, land, labor, capital, and intermediate materials quantity and prices. A detailed description of data is available in Ball (1984). The data were aggregated using a discrete Tornquist approximation of a Divisia index. Tornquist price indices are computed first, and then implicit quantity indices are computed by dividing value (revenue or expenditures) by the Tornquist price index.

Labor data were formulated to account for differences in the productivity of different types of workers and changes in quality due to education. The price index corresponding to the Tornquist index of labor input is defined as the ratio of labor compensation (or imputed compensation) to the Tornquist quantity index. For capital, the separation of price and quantity components of outlays is based on the correspondence between the value of an asset and the discounted value of its services (Griliches and Jorgenson, 1966). The service price depends on the asset price, the rate of return, and the rate of replacement. Outlays on capital are separated into prices and quantity components by combining the rate of return with the other components of the service price. Fertilizer information on primary nutrient content is used to account for quality changes.

The implicit rental or service price depends on the asset price, rate of economic depreciation, service life, tax treatment, and the discount rate. Asset prices, the rate of economic depreciation, and service lives are taken from Ball (1985). The tax parameters such as the depreciation method, tax life, and investment tax credit are based on eligibility requirements at the time the asset was purchased. If more than one option was allowable, the method resulting in the lowest rental rate was selected. The marginal ex ante Federal income tax rates developed for this analysis are interpreted as the expected tax rate an investor or firm would pay on an additional dollar of income prior to undertaking any new investment. These ex ante rates are estimated for sole proprietorships from U.S. Department of the Treasury data for 1962-78.

Prior to the Revenue Act of 1964, the lowest marginal tax rate applied to all taxable income below $2,000. It was assumed that the appropriate marginal tax rate corresponded to the lowest tax bracket. Therefore, the ex ante marginal tax rate from 1955-61 was 20 percent.

The discount rate is assumed to be a weighted average of the longrun real interest rate (external financing) and the longrun real return to equity (internal financing). Weights were computed from Bureau of Census data (1974, 1982). Interest rates for external financing were computed from rates charged by Federal land banks on new farm loans. The longrun rate of return to equity is based on Melichar (1981) and Gertel (1982).

Intermediate inputs include feed, seed, purchased livestock, chemical fertilizers, lime, pesticides, petroleum fuels, natural gas, and electricity. Output consisted of an index of 118 agricultural commodities from seven categories: cash grains, field crops except cash grains, vegetables and melons, fruits and tree nuts, livestock excluding dairy, poultry and animal specialties, dairy products, and poultry and eggs.

Cash balances are defined as the sum of currency and demand deposits held by the agricultural sector (U.S. Department of Agriculture, 1984).

Following the approach suggested by Barnett, Offenbacher, and Spindt (1984), monetary assets are viewed as durable goods which provide their holders with a flow of monetary services. These services are priced by the user cost of the monetary asset from which they flow (Barnett, 1978). The user cost is a monetary asset analog of the Jorgensonian user cost (rental price) of durable consumer goods. As defined by Barnett (1978), the user cost of money is:

$$P_{mt} = D_t(R_t - r_t)/(1 + R_t) \qquad t = 1,2,\ldots, T \qquad (8)$$

where P_m is the user cost of money, D is an aggregate price index of goods and services, R represents the yield on bond holdings, and r is the nominal yield on the monetary asset. R_t is the benchmark rate and represents the yield on assets accumulated for the purpose of transferring wealth between multiperiod planning horizons rather than to provide liquidity or other monetary services during the current period. Although the yield on a completely illiquid asset such as human capital might best fit this description, no satisfactory empirical series for the rate of return on human capital is available.

In this analysis D is the GNP implicit price deflator, R is the yield on Moody's BAA bonds, and r is the yield on 3-month commercial paper. Choice of components follow those of Barnett and Spindt (1982) in their construction of the implicit rental rate of currency and demand deposits. It is assumed that farmers earn the full competitive rate on their holdings. Using Klein's (1974) methodology, an implicit full competitive rate of return on demand deposits is constructed.

ESTIMATED MODEL

Nonzero interequation covariance was captured by jointly estimating the cost-share equations using a full information maximum likelihood methodology. Because the cost shares sum to unity, the stochastic error term must sum to zero at each observation. This constraint implies the covariance structure is not of full rank and one equation must be dropped before the system is estimated. The maximum likelihood estimator, however, assures the estimated coefficients are invariant to which equation is deleted (Barten, 1969). In this analysis, the cost-share equation associated with intermediate materials was omitted.

The estimated parameters and associated asymptotic standard errors and t-statistics are given in table 1. Only 2 of the 12 estimated parameters have asymptotic t-statistics of less than one. Four of the five parameters associated with money manifest fairly strong t-statistics. Only the parameter associated with money and labor is weak.

Demand price elasticities are derived using the estimated parameters given in table 2 and the relationships described by equations (4) and (5).7/ All the estimated own-price elasticities have the correct negative sign. The estimates indicate intermediate materials are the least elastic and money the most. Furthermore, the results suggest machinery is a substitute with labor. The machinery-intermediate material elasticity, although negative, is virtually zero. Money is a substitute with both machinery and labor and a complement with only intermediate materials. Therefore, as the cost of holding real money balances rises, labor

7/ Allen partial elasticities of substitution are easily derivable from the input demand price elasticities and are, therefore, not reported here.

and machinery are substituted. These results are generally consistent with Dennis and Smith (1978) who found money to be a substitute with capital in all 11 two-digit SIC code industries studied and a substitute with production labor in 9 out of 11 industries.

Table 1--Estimated parameters and associated statistics

Coefficient	Value	Asymptotic standard error	Asymptotic t-statistic
bm	0.07539	0.3748	2.01
bmm	.0164	.0013	7.99
blm	- .0014	.0031	- .46
bcm	- .0049	.0027	-1.82
bzm	- .0548	.0286	-1.92
bc	12.66	1.224	10.35
bcc	.1156	.0240	4.81
blc	- .0153	.0261	- .59
bzc	- .9253	.0938	9.87
bl	-17.42	1.542	-11.30
bll	.0454	.0335	1.35
bzl	1.35	.1182	11.43

Note: Coefficient symbols are defined as follows: b_i intercept parameter, b_{ij} parameter associated with the effect of the jth price on the ith cost share, b_{zi} parameter associated with the effect of land on the ith cost share; where m = money, l = labor, c = machinery, and f = intermediate materials. All input prices P_i are normalized on P_f.

Table 2--Input demand price elasticities 1/

Input \ Price	Labor	Machinery	Intermediate materials	Money
Labor	-0.56	0.49	0.06	0.13
Machinery	.24	-.24	-.01	.01
Intermediate material	.09	-.03	-.06	-.01
Money	.22	.40	.05	-.67

1/ Computed at mean values.

A likelihood ratio test was conducted to statistically test the maintained hypothesis that a production model which incorporates money is statistically superior to a production model which does not. The test statistic is

$$-2\ln(L) = T[\ln(|\Omega_R|/|\Omega_u|)] \tag{9}$$

where L is the likelihood ratio, $|\Omega_R|$ is the determinant of the restricted estimator of the variance-covariance matrix for the cost-share equations' errors, $|\Omega_u|$ is the unrestricted estimator of the variance-covariance matrix, and T is the number of observations. This statistic is distributed asymptotically as a chi-square with degrees of freedom equal to the independently imposed restrictions. In this case, five restrictions are imposed, $\ln|\Omega_R| = 18.42$, and $\ln|\Omega_u| = 29.67$. The null hypothesis of no statistical difference between the restricted model (without money) and the unrestricted model (with money) is rejected at any reasonable level or significance.

MODEL SIMULATION RESULTS

As an example of its potential application, the model is simulated over a 10-year period assuming a 10-percent increase in the user cost of money per period. All other variables are fixed at their 1978 values. The simulation results are shown in table 3.

The effects on cost shares are generally consistent with the estimated elasticities results (table 3). The inelastic demand for real cash balances and the increase in the cost of holding money lead to an increase in its cost share. The declining cost share for intermediate materials and initial increase in the cost share for machinery adhere to their respective negative and positive cross-price elasticities of demand with respect to real cash balances. For labor, the initial decline in its share is not consistent with its positive cross-price elasticity with respect to money. However, this decline may reflect the increased substitution of machinery initially in production. Labor's constant share after the second simulation period then corresponds to the slight reduction in machinery's share for the remaining simulation periods.

The simulation example illustrates that macroeconomic policies affecting interest rates and thus the user cost of money will, in turn, affect the composition of inputs used in agricultural production. Although the magnitude of changes in input shares is not large, there are definite effects on other input demands. When *ceteris paribus* assumptions are relaxed, the effect on agricultural structure can be significant.

SUMMARY AND CONCLUSIONS

In this analysis, real cash balances are integrated into a characterization of aggregate agricultural production. As suggested by Friedman, money is cast as a neoclassical input rather than as a buffer as in inventory theoretic approaches. As opposed to defining production in a strict engineering sense, the production concept is extended to a "delivered output" function which encompasses inputs and the contributions of money. Within this framework, money is cast as an input which facilitates the flow of inputs and outputs in a world where production is not instantaneous.

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Table 3--Simulated cost shares 1/

Period	Cost shares			
	Labor	Machinery	Intermediate materials	Money
1	0.1874	0.6089	0.1807	0.0231
2	.1855	.6197	.1713	.0234
3	.1855	.6193	.1710	.0241
4	.1855	.6189	.1707	.0249
5	.1855	.6185	.1704	.0256
6	.1855	.6181	.1700	.0264
7	.1855	.6177	.1697	.0271
8	.1855	.6173	.1694	.0278
9	.1855	.6169	.1691	.0285
10	.1855	.6165	.1688	.0293

1/ May not sum to 1 due to rounding.

Note: 1. User cost of money increases 10 percent per period for 10 periods.
2. All other prices and values (i.e. land) fixed at 1978 levels.

The empirical results suggest money is an important contributor to aggregate agricultural production and its exclusion offers the potential for a serious specification bias. The null hypothesis of no statistical difference between a input cost-share system without real cash balances and one with real cash balances is easily rejected. Within this context, the real cash balances version is judged superior for the data used in this analysis. This, of course, is not equivalent to rejecting the restricted (no real cash balances) model. The alternative hypothesis that a different model specification may produce different results cannot be rejected. Estimated parameters are used to calculate input demand elasticities. The results indicate the demand for real cash balances is relatively inelastic to changes in the user cost of money, and real cash balances are a substitute with machinery and capital. Future research should extend the range of financial assets held by farmers into the real cash balances concept. 8/ Results from this analysis suggest greater attention to the role of money in agricultural production decisionmaking is warranted.

8/ See Barth, Kraft, and Kraft (1977) for a discussion of the 'moneyness' of financial assets. Fischer (1974) argues that delivered output production functions can be extended so that inventories of goods appear as factors.

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